

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 952 347 A1

(12)

## EUROPEAN PATENT APPLICATION

(43) Date of publication:  
27.10.1999 Bulletin 1999/43

(21) Application number: 98309534.0

(22) Date of filing: 20.11.1998

(51) Int. Cl.<sup>6</sup>: F04B 35/04, F04B 49/06,  
H02K 33/16, H02K 33/10,  
H02K 1/12, H02K 1/20

(84) Designated Contracting States:  
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU  
MC NL PT SE  
Designated Extension States:  
AL LT LV MK RO SI

(30) Priority: 20.04.1998 JP 10911098  
21.04.1998 JP 11047398

(71) Applicant:  
Matsushita Refrigeration Company  
Higashi, Osaka-shi, Osaka 577-0066 (JP)

(72) Inventors:  
• Morita, Ichiro  
Fujisawa-shi, Kanagawa-ken 251-0042 (JP)

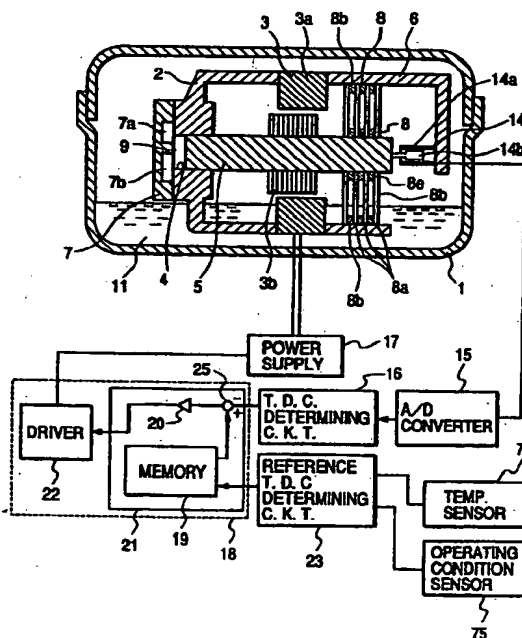
• Kobayashi, Masanori  
Fujisawa-shi, Kanagawa-ken 251-0861 (JP)  
• Inagaki, Koh  
Fujisawa-shi, Kanagawa-ken 251-0861 (JP)  
• Katayama, Makoto  
Zushi-shi, Kanagawa-ken 249-0005 (JP)

(74) Representative:  
Senior, Alan Murray  
J.A. KEMP & CO.,  
14 South Square,  
Gray's Inn  
London WC1R 5LX (GB)

## (54) Piston stroke control circuit for an oscillating compressor

(57) A linear hermetic compressor is provided which may be employed in refrigerators or air conditioners. The compressor includes a linear motor (3) and a piston oscillation controller (18), controlling the control oscillations of the piston so as to bring an actual top dead center position of the piston into agreement with a reference top dead center position and altering the reference top dead center position based on a given parameter such as the ambient temperature or a required thermal load of, for example, a refrigerator.

FIG. 1



## Description

[0001] The present invention relates generally to an improved structure of a linear compressor which may be used in refrigerators or air conditioners.

[0002] Japanese Patent First Publication No. 8-247025 discloses a linear compressor for use in a refrigerator which is designed to keep a top clearance between a cylinder head and the head of a piston when lying at the top dead center constant for avoiding an overstroke of the piston. The linear compressor, however, has the drawback in that a decrease in ambient temperature or thermal load of the refrigerator results in excess of a refrigerating capacity because of the constant top clearance.

[0003] The conventional linear compressor also encounters another drawback in that the efficiency of a linear motor which moves the piston linearly is poor because of an increased copper loss of a coil.

[0004] It is therefore an aim of the present invention to avoid the disadvantages of the prior art.

[0005] It is another aim of the present invention to provide an improved structure of a compressor which has a high efficiency.

[0006] According to one aspect of the present invention, there is provided a linear compressor which comprises: (a) a hermetic casing; (b) a block having formed therein a cylinder within which a piston oscillates to change a volume of a compression chamber; (c) a linear motor moving the piston within the cylinder in a first direction; (d) an elastic unit which is connected at a first portion to the block and at a second portion to the piston to urge the piston in a second direction opposite the first direction in response to the movement of the piston through the linear motor so that the piston oscillates in the cylinder; (e) a piston position sensor detecting a position of the piston to provide a position signal indicative thereof; (f) a top dead center position determining circuit determining an actual top dead center position of the piston based on the position signal provided by the piston position sensor; (g) an oscillation control circuit controlling oscillation of the piston so that a difference between the actual top dead center position and a reference top dead center position of the piston is decreased; and (h) a reference top dead center position changing circuit changing the reference top dead center position.

[0007] In the preferred mode of the invention, an ambient temperature sensor is further provided which measures an ambient temperature. The reference top dead center position changing circuit changes the reference top dead center position based on the ambient temperature measured by the ambient temperature sensor.

[0008] An operating condition determining circuit is further provided which determines a compressor output request. The reference top dead center position changing circuit changes the reference top dead center position based on the compressor output request

determined by the operating condition determining circuit.

[0009] According to the second aspect of the invention, there is provided a linear compressor which comprises: (a) a hermetic casing; (b) a block having formed therein a cylinder within which a piston oscillates to change a volume of a compression chamber; (c) a linear motor including a stator and a rotor, the rotor being connected to the piston to move the piston within the cylinder in a first direction; (d) an elastic unit which is connected at a first portion to the block and at a second portion to the piston to urge the piston in a second direction opposite the first direction in response to the movement of the piston through the linear motor so that the piston oscillates in the cylinder; (e) a pressure chamber formed in the block; (f) a stator moving member having disposed thereon the stator of the linear motor, the stator moving member being mounted within the pressure chamber slidably in the first and second directions; (g) first and second back pressure chambers defined in the pressure chamber on both sides of the stator moving member; and (h) a pressure controlling mechanism controlling a difference in pressure between the first and second back pressure chambers to shift the stator moving member, thereby moving the stator to a desired position.

[0010] In the preferred mode of the invention, the block also has formed therein an inlet and an outlet communicating with the compression chamber. The pressure controlling mechanism selectively establishes and blocks communications between the inlet and the first back pressure chamber and between the outlet and the second back pressure chamber.

[0011] An urging mechanism is further provided which urges the stator of the linear motor away from the compression chamber.

[0012] According to the third aspect of the invention, there is provided a linear motor which comprises: (a) a rotor; and (b) a stator including a coil and an annular yoke retaining therein the coil, the yoke being made of a plurality of arc-shaped blocks each of which has formed therein a groove in which a peripheral portion of the coil is fitted.

[0013] According to the fourth aspect of the invention, there is provided a linear motor which comprises: (a) a rotor; and (b) a stator including an annular yoke, the yoke being formed with a plurality of blocks each constituting a circumferential portion of the yoke, each of the blocks including a central section and first and second outer sections disposed on both sides of the central section, the central section being made consisting of laminations made from a material having a higher permeability, the first and second outer sections each being made from a material having a permeability lower than that of the central section and an electric resistance greater than that of the central section.

[0014] In the preferred mode of the invention, the laminations making up the central section of each of the

blocks of the yoke are laid to overlap each other in a circumferential direction of the yoke.

[0015] The central section of each of the blocks of the yoke is quadrangular prism-shaped, and each of the first and second outer sections is triangular prism-shaped.

[0016] The central section and the first and second outer sections are joined to each other using resin.

[0017] The first outer section of each of the blocks of the yoke has a protrusion formed on a surface facing in a circumferential direction of the yoke. The second outer section has formed in a surface facing the circumferential direction of the yoke a groove in which the protrusion is fitted for joining the blocks to each other to complete the yoke.

[0018] According to the fifth aspect of the invention, there is provided a linear motor which comprises: (a) a rotor; (b) a stator including an annular yoke, the yoke being formed with a plurality of blocks each constituting a circumferential portion of the yoke, each of the blocks being formed with laminations made from a material having a higher permeability; and (c) an annular retainer retaining the blocks on an inner surface thereof at regular intervals in a circumferential direction of the retainer, the retainer including a strip member and holders, the strip member being made from a material having a permeability lower than that of the yoke and an electric resistance greater than that of the yoke, each of the holders holding therein one of the blocks and being glued on the strip member.

[0019] In the preferred mode of the invention, each of the holders is made of a C-shaped member having disposed therein one of the blocks.

[0020] The present invention will be understood more fully from the detailed description given hereinbelow and from the accompanying drawings of the preferred embodiment of the invention, which, however, should not be taken to limit the invention to the specific embodiment but are for explanation and understanding only.

In the drawings:

[0021]

Fig. 1 is an illustration which shows a linear compressor according to the first embodiment of the invention;

Fig. 2 is a graph which shows the efficiency of a linear compressor and a reference top dead center position in terms of the refrigerating capacity;

Fig. 3 is a cross sectional view which shows a linear compressor according to the second embodiment of the invention;

Fig. 4 is a cross sectional view which shows a linear compressor according to the third embodiment of the invention;

Fig. 5 is a partially cross sectional view which shows a linear motor may be used in linear com-

pressors of the first to third embodiments;

Fig. 6 is a top view which shows an outer yoke of the linear motor of Fig. 5;

Fig. 7 is a longitudinal cross sectional view taken along the line VII-VII in Fig. 6;

Fig. 8 is a perspective view which shows fabrication of a coil fitted in the outer yoke of Figs. 6 and 7;

Fig. 9 is a perspective view which shows one of separate blocks making up the outer yoke of Figs. 6 and 7;

Fig. 10 is a top view which shows a modification of the outer yoke in Fig. 5;

Fig. 11 is a side view of Fig. 10;

Fig. 12 is a perspective view which shows one of the separate blocks of Figs. 10 and 11;

Fig. 13 is a top view which shows a second modification of the outer yoke in Fig. 5;

Fig. 14 is a perspective view which shows one of separate blocks in Fig. 13; and

Fig. 15 is a perspective view which shows a block retainer in Fig. 13.

[0022] Referring now to the drawings, particularly to Fig. 1, there is shown a linear compressor (also called a vibrating compressor) according to the present invention which. The following discussion will refer to the linear compressor as being used in a refrigerating system such as a refrigerator, but the present invention is not limited to the same.

[0023] The linear compressor includes generally a hermetic casing 1 and a compressor mechanism 2.

[0024] The compressor mechanism 2 includes a linear motor 3, a cylinder 4, a piston 5, a hollow block 6, a cylinder head 7, and a spring assembly 8 and is supported within the casing 1 through suspension springs (not shown). A lubricating oil 11 is settled on the bottom of the casing 1.

[0025] The block 6 has formed therein the cylinder 4 within which the piston 5 reciprocates to suck, for example, a refrigerant from the inlet 7a into a compression chamber 9 and to discharge it from the outlet 7b to the refrigerating system.

[0026] The motor 3 consists of an annular stator 3a and a rotor 3b mounted on the piston 5. The stator 3a is mounted in a peripheral wall of the block 6. Instead of the motor 3, any other known moving mechanisms may be used which are capable of reciprocating the piston 5.

[0027] The spring assembly 8 which consists of four spring discs 8a laid to overlap each other and outer and inner annular spacers 8b and 8c disposed between adjacent two of the spring discs 8a. Each of the spring discs 8a has formed therein, for example, arc-shaped slits to define spring arms and is connected at the center to the periphery of the piston 5 and at an outer edge to an inner wall of the hollow block 6.

[0028] The linear compressor also includes a piston position sensor 14, an A/D converter 15, a top dead center determining circuit 16, a reference top dead

center position determining circuit 23, an oscillation controller 18, and an ac power supply 17. The oscillation controller 18 includes a reciprocating motion controller 21 and a base driver 22. The reciprocating motion controller 21 includes a reference top dead center position memory 19, an amplifier 20, a comparator 25.

[0029] The piston position sensor 14 is implemented by a differential transformer and consists of a cylindrical coil 14a and a core 14b made of a permanent magnet. The cylindrical coil 14a is connected to an inner end wall of the hollow block 6. The core 14b is connected to the bottom of the piston 5. The movement of the core 14b (i.e., the piston 5) causes the coil 14a to output an electric signal indicative of the position of the piston 5 in an analog form to the A/D converter 15. The A/D converter 15 converts the input signal into a digital signal and outputs it to the top dead center determining circuit 16. The top dead center determining circuit 16 monitors the position of the piston 5 based on the signal from the A/D converter 15 to output a top dead center signal to the reciprocating motion controller 21 when the piston 5 has reached the top dead center. The reciprocating motion controller 21 compares through the comparator 25 an actual top dead center position of the piston 5 indicated by the top dead center signal with a reference top dead center position stored in the reference top dead center position memory 19 to change the amplitude of a voltage signal outputted through the amplifier 20 to the base driver 22 according to the difference between the actual top dead center position and the reference top dead center position. The base driver 22 controls the supply of power (i.e., an output voltage) from the power supply 17 to the motor 3 based on the inputted voltage signal to adjust the movement of the piston 5 so that the difference between the actual top dead center position and the reference top dead center position is decreased to zero.

[0030] The reference top dead center position determining circuit 23 is connected to a temperature sensor 70 and an operating condition sensor 75. The temperature sensor 70 measures an ambient temperature. The operating condition sensor 75 monitors a given operating condition such as a required thermal load (i.e., a refrigeration demand) of the refrigerating system as a function of the temperature within a refrigerating chamber of the refrigerating system (e.g., a refrigerator).

[0031] The reference top dead center position determining circuit 23 alters the reference top dead center position stored in the memory 19 according to the ambient temperature measured by the temperature sensor 70 and the operating condition of the refrigerating system monitored by the operating condition sensor 75.

[0032] In operation, when the power supply 17 is turned on, the rotor 3b of the motor 3 is excited and attracted in a horizontal direction, as viewed in the drawing, along with the piston 5, pressing the spring assembly 8. The spring assembly 8 produces a reactive force to move the piston 5 in the opposite direction, thereby

causing the piston 5 to oscillate, increasing and decreasing the volume of the compression chamber 9 alternately.

[0033] The oscillation controller 18 adjusts, as described above, the output voltage from the power supply 17 to the motor 3 so that the difference between the actual top dead center position of the piston 5 monitored by the piston position sensor 14 and the reference top dead center position stored in the memory 19 may be decreased to zero. The top clearance of the piston 5 (i.e., the gap between the head of the piston 5 at the top dead center and an inner wall of the cylinder head 7) is, thus, kept constant.

[0034] When the ambient temperature and/or the required thermal load monitored by the temperature sensor 70 and the operating condition sensor 75 are decreased, it will cause a required refrigerating capacity of the linear compressor to be lowered. The reference top dead center position determining circuit 23 selects one of reference top dead center positions by look-up using a map based on the monitored ambient temperature and the thermal load of the refrigerating system and alters the reference top dead center position now stored in the memory 19 of the reciprocating motion controller 21 so as to increase the top clearance of the piston 5. An increase in top clearance of the piston 5 causes the refrigerating capacity of the linear compressor to be lowered, thereby avoiding the excess of the compression capacity of the linear compressor (i.e., the capacity of the refrigerating system).

[0035] The linear compressor may also include a quick refrigeration manual switch (not shown) which is installed in an operation panel of the refrigerator. When the quick refrigeration manual switch is turned on by an operator, the reference top dead center position determining circuit 23 alters the reference top dead center position stored in the memory 19 so as to decrease the top clearance of the piston 5 for enhancing the refrigerating capacity regardless of the outputs from the temperature sensor 70 and the operating condition sensor 75.

[0036] Fig. 2 shows results of tests performed by the inventors of this application and shows that a change in reference top dead center position to increase the top clearance of the piston 5 causes the refrigerating capacity of the linear compressor to be lowered, but the efficiency of the linear compressor hardly changes until a ratio of the volume of the top clearance of the piston 5 to the volume of the cylinder 4 reaches 10%. Specifically, within a range of the ratio of the volume of the top clearance of the piston 5 to the volume of the cylinder 4 of 10%, the refrigerating capacity may be lowered to approximately half according to the environmental and refrigerating conditions without degrading the efficiency of the linear compressor and the entire refrigerating system.

[0037] Fig. 3 shows a linear compressor according to the second embodiment of the invention. The same ref-

erence numbers as employed in Fig. 1 refer to the same parts, and explanation thereof in detail will be omitted here.

[0038] The linear compressor includes an annular stator moving base 27, a pressure control system 25, and a controller 100.

[0039] The stator moving base 27 rigidly holds the stator 3a of the motor 3 on an inner wall thereof and is disposed within an annular chamber 50 formed in a peripheral wall of the hollow block 6. The annular chamber 50 has first and second back pressure chambers 26a and 26b defined between ends of the annular chamber 50 and ends of the stator moving base 37, respectively.

[0040] The pressure control system 25 includes pressure control valves 25a, 25b, 25c, and 25d, connecting pipes 25e, 25f, 25g, and 25h, and pressure pipes 25i and 25j. The connecting pipes 25e and 25f connect a suction pipe 24 which leads to the inlet 7a of the compressor mechanism 2 with the pressure control valves 25a and 25b, respectively. The connecting pipes 25g and 25h connect a discharge pipe 10 which leads to the outlet 7b of the compressor mechanism 2 with the pressure control valves 25c and 25d, respectively. The pressure pipe 25i connects the pressure control valves 25a and 25c with the back pressure chamber 28b through a back pressure pipe 26b extending through the casing 1. The pressure pipe 25j connects the pressure control valves 25b and 25d with the back pressure chamber 28a through a back pressure pipe 26a extending through the casing 1. Each of the pressure control valves 25a to 25d is, for example, a solenoid valve which is actuated by the controller 100.

[0041] The linear compressor of this embodiment also includes a temperature sensor 70 measuring the ambient temperature and a pressure sensor 77 measuring the pressure of a refrigerant within the discharge pipe 10 which are connected to the controller 100.

[0042] When the ambient temperature and/or the pressure of the refrigerant discharged from the outlet 7b of the compressor mechanism 2 are decreased, it will cause the piston 5 to be moved left, as viewed in the drawing, over the top dead center so that it may collide with the inner wall of the cylinder head 7. Therefore, when either or both of outputs from the temperature sensor 70 and the pressure sensor 77 exceed given lower threshold values, the controller 100 opens the pressure control valves 25a and 25d while it closes the pressure control valves 25b and 25c to establish communications between the back pressure chamber 28a and the outlet 7b and between the back pressure chamber 28b and the inlet 7a of the compressor mechanism 2. The inner pressure of the back pressure chamber 28a is, thus, increased, while the pressure of the back pressure chamber 28b is decreased, thereby causing the stator moving base 27 to be urged right, as viewed in the drawing, to shift the center of oscillation of the piston 5 away from the cylinder block 7. This avoids the col-

lision of the piston 5 with the inner wall of the cylinder head 7 which will contribute to unwanted mechanical noise and damage of the piston 5.

[0043] Fig. 4 shows a linear compressor according to the third embodiment of the invention which is different from the one shown in Fig. 3 only in that a coil spring 29 is disposed between a holder 45 mounted on an inner wall of the hollow block 6 and the stator 3a of the linear motor 3 which produces a spring pressure to hold the stator 3a from being shifted left, as viewed in the drawing. Other arrangements are identical, and explanation thereof in detail will be omitted here.

[0044] When the linear compressor of the second embodiment in Fig. 3 is turned off, the linear motor 3 may be stopped with the stator 3a being shifted left, as viewed in the drawing, away from a desired center of oscillation of the piston 5. When the linear compressor is turned on from this state, it may cause the piston 5 to pass over the top dead center and collide with the inner wall of the cylinder block 7. The coil spring 45 of this embodiment, as described above, holds the stator 3a in a desired position (e.g., the desired center of oscillation of the piston 5) when the pressures within the back pressure chambers 28a and 28b are balanced after the linear compressor is turned off, thereby avoiding the collision of the piston 5 with the inner wall of the cylinder block 7 immediately after the linear compressor is turned on.

[0045] Instead of the coil spring 29, an elastic member such as rubber may be used.

[0046] Fig. 5 shows a linear motor 3 which may be employed in the above embodiments.

[0047] The linear motor 3 consists essentially of a stator 3a and a rotor 3b. The stator 3a includes an annular inner yoke 101, an annular outer yoke 104, and a coil 106. The inner yoke 101 and the outer yoke 104 are secured on the hollow block 6, as shown in Fig. 1. The outer yoke 104 has two magnetic poles 102 and 103. The rotor 3b includes a cylindrical permanent magnet 107 and has the piston 5 pass through the bottom thereof.

[0048] The outer yoke 104 includes, as shown in Fig. 6, a plurality of separate blocks 104a, 104b, 104c, and 104d whose end surfaces 114a, 114b, 114c, and 114d are glued or welded to each other. Each of the blocks 104a to 104d has, as shown in Figs. 7 and 9, formed in an inner wall thereof a groove 113 in which the coil 106 is fitted.

[0049] The outer yoke 104 may be formed with at least two separate blocks.

[0050] In fabrication of the coil 106 and the outer yoke 104, the coil 106 is, as shown in Fig. 8, first made by tensioning and winding wire around a bobbin 150 outward in a radial direction at high density. Next, the bobbin 150 is drawn from the coil 106 and fitted into the grooves 113 of the blocks 104a to 104d of the outer yoke 104. Finally, the blocks 104a to 104d are glued or welded to each other to make up the outer yoke 104.

[0051] The coil 106 may be impregnated with a resin liquid for avoiding deformation and protection thereof.

[0052] In conventional linear motors, a stator is usually made by winding wire within a groove formed in an inner wall of a one-piece annular outer yoke inward in a radial direction. It is, thus, difficult to wind the wire under high tension. In contrast to this, the stator 3a of this embodiment is, as described above, made by fitting the coil 106, which is formed by winding the wire outward in the radial direction under high tension, in the grooves 113 of the blocks 104a to 104d and joining the blocks 104a to 104d to complete the outer yoke 104. The coil 106 of this embodiment, therefore, has a higher space factor and a greater number of turns per volume as compared with the conventional linear motors. This reduces a copper loss that is proportional to the square of current flowing through the coil, thereby resulting in greatly improved efficiency of the linear motor 3.

[0053] Figs. 10, 11, and 12 show the first modification of the outer yoke 104 used in the linear motor 3.

[0054] The outer yoke 104 of this embodiment includes twelve fan-shaped separate blocks 104a identical in size and shape with each other. Each of the separate blocks 104a consists of a central portion 80 and first and second outer portions 90 and 101. The central portion 80 is formed with quadrangular prism-shaped laminations 70 made from a material having a higher permeability. The first and second outer portions 90 and 101 are each formed with a triangular prism-shaped member made from, for example, resin having the permeability lower than that of the central portion 80 and the electric resistance greater than that of the central portion 80. Each of the blocks 104 is fabricated by sandwiching the central portion 80 between the first and second portions 90 and 101 and impregnating them with resin.

[0055] Each of the first outer portions 90 has, as shown in Figs. 10 and 12, formed therein a circular recess or groove 210. Each of the second outer portions 101 has, as clearly shown in Fig. 12, formed therein a cylindrical protrusion 220. The assembly of the outer yoke 104 is accomplished by inserting the cylindrical protrusion 220 of each of the second outer portions 101 into the circular groove 210 of one of the first outer portion 90 from an axial direction thereof to join all the blocks 104a.

[0056] Each of the blocks 104 may be surface-finished before the outer yoke 104 is assembled. Alternatively, the outer yoke 104 may be surface-finished after being assembled.

[0057] The eddy current loss of a linear motor is usually proportional to the square of the thickness of a yoke, but decreased greatly in this embodiment by the formation of the central portion 80 of the outer yoke 104 with the laminations 70 having the higher permeability, which results in greatly improved efficiency of the linear motor 3.

[0058] Each of the blocks 104, as described above,

has disposed on both sides of the central portion 70 the first and second outer portions 90 and 101 each having the lower permeability and higher resistance, thereby minimizing the leakage of magnetic flux from the central portion 70 of each of the blocks 104 to adjacent one, thus resulting in a decrease in copper loss.

[0059] The outer yoke 104 of this embodiment does not have the coil 106, but may have the same as needed.

[0060] The inner yoke 101 shown in Fig. 5 may be fabricated in the same manner as described above.

[0061] Figs. 13, 14, and 15 show the first modification of the outer yoke 104 used in the linear motor 3.

[0062] The outer yoke 104 of this embodiment includes twelve separate blocks 215 and an annular block retainer 216. Each of the blocks 215 is, as clearly shown in Fig. 14, formed with quadrangular prism-shaped laminations 217 made from a material having a higher permeability. The block retainer 216, as clearly shown in Fig. 15, consists of a strip member 219 and twelve C-shaped holders 218. The strip member 219 is flexible and made of, for example, resin which has the permeability lower than that of the blocks 215 and the resistance greater than that of the blocks 215. This avoids the flow of magnetic flux through the strip member 219 between adjacent two of the blocks 215, thereby minimizing the copper loss.

[0063] The C-shaped holders 218 are glued on an inner surface of the strip member 219 at regular intervals and hold therein the blocks 215, as shown in Fig. 13, in a circumferential direction with regular gaps 220. The formation of the gaps 220 between adjacent two of the blocks 215 increases a surface area of the outer yoke 104, thereby facilitating the cooling of the linear motor 3.

[0064] The outer yoke 104 of this embodiment does not have the coil 106, but may have the same as needed.

[0065] The inner yoke 101 shown in Fig. 5 may be fabricated in the same manner as described above.

[0066] While the present invention has been disclosed in terms of the preferred embodiment in order to facilitate a better understanding thereof, it should be appreciated that the invention can be embodied in various ways without departing from the principle of the invention. Therefore, the invention should be understood to include all possible embodiments and modification to the shown embodiments which can be embodied without departing from the scope of the invention as set forth in the appended claims.

## Claims

### 1. A linear compressor comprising:

- a hermetic casing;
- a block having formed therein a cylinder within which is provided a piston which can oscillate

to change the volume of a compression chamber;

a linear motor for moving the piston within the cylinder in a first direction; biasing means connected at a first portion to said block and at a second portion to the piston to urge the piston in a second direction opposite the first direction in response to the movement of the piston through said linear motor so that the piston oscillates in the cylinder;

a piston position sensor for detecting a position of said piston to provide a position signal indicative thereof;

a top dead center position determining circuit for determining an actual top dead center position of said piston based on the position signal provided by said piston position sensor;

an oscillation control circuit for controlling oscillation of the piston so that a difference between the actual top dead center position and a reference top dead center position of the piston is decreased; and

a reference top dead center position changing circuit for changing the reference top dead center position.

2. A linear compressor according to claim 1, further comprising an ambient temperature sensor for measuring an ambient temperature, and wherein said reference top dead center position changing circuit is adapted to change the reference top dead center position based on the ambient temperature measured by said ambient temperature sensor.

3. A linear compressor according to claim 1 or 2, further comprising an operating condition determining circuit for determining a compressor output request, and wherein said reference top dead center position changing circuit is adapted to change the reference top dead center position based on the compressor output request determined by said operating condition determining circuit.

4. A linear compressor comprising:

a hermetic casing;

a block having formed therein a cylinder within which is provided a piston which can oscillate to change the volume of a compression chamber;

a linear motor including a stator and a rotor, the rotor being connected to the piston for moving the piston within the cylinder in a first direction; biasing means connected at a first portion to said block and at a second portion to the piston to urge the piston in a second direction opposite the first direction in response to the movement of the piston through said linear motor so

that the piston oscillates in the cylinder;

a pressure chamber formed in said block; a stator moving member having disposed thereon the stator of said linear motor, said stator moving member being mounted within said pressure chamber slidably in the first and second directions;

first and second back pressure chambers defined in said pressure chamber on both sides of the stator moving member; and

a pressure controlling mechanism for controlling a difference in pressure between said first and second back pressure chambers to shift said stator moving member, thereby moving the stator to a desired position.

5. A linear compressor according to claim 4, wherein said block also has formed therein an inlet and an outlet communicating with the compression chamber, and wherein said pressure controlling mechanism is adapted to selectively establish and block communications between the inlet and the first back pressure chamber and between the outlet and the second back pressure chamber.

6. A linear compressor according to claim 4 or 5, further comprising an urging mechanism which urges the stator of said linear motor away from the compression chamber.

7. A linear motor comprising:

a rotor; and

a stator including a coil and an annular yoke retaining therein the coil, the yoke being made of a plurality of arc-shaped blocks each of which has formed therein a groove in which a peripheral portion of the coil is fitted.

8. A linear motor comprising:

a rotor; and

a stator including an annular yoke, the yoke being formed with a plurality of blocks each constituting a circumferential portion of the yoke, each of the blocks including a central section and first and second outer sections disposed on both sides of the central section, the central section being made consisting of laminations made from a material having a higher permeability, the first and second outer sections each being made from a material having a permeability lower than that of the central section and an electric resistance greater than that of the central section.

9. A linear motor according to claim 8, wherein the laminations making up the central section of each

of the blocks of the yoke are laid to overlap each other in a circumferential direction of the yoke.

10. A linear motor according to claim 9, wherein the central section of each of the blocks of the yoke is quadrangular prism-shaped, and each of the first and second outer sections is triangular prism-shaped. 5

11. A linear motor according to claim 8, 9 or 10, wherein the central section and the first and second outer sections are joined to each other using resin. 10

12. A linear motor according to claim 8, 9, 10 or 11, wherein the first outer section of each of the blocks of the yoke has a protrusion formed on a surface facing in a circumferential direction of the yoke, and the second outer section has formed in a surface facing the circumferential direction of the yoke a groove in which the protrusion is fitted for joining the blocks to each other to complete the yoke. 15 20

13. A linear motor comprising:

a rotor; 25  
a stator including an annular yoke, the yoke being formed with a plurality of blocks each constituting a circumferential portion of the yoke, each of the blocks being formed with laminations made from a material having a higher permeability; and 30  
an annular retainer retaining the blocks on an inner surface thereof at regular intervals in a circumferential direction of the retainer, said retainer including a strip member and holders, 35  
the strip member being made from a material having a permeability lower than that of the yoke and an electric resistance greater than that of the yoke, each of the holders holding therein one of the blocks and being glued on the strip member. 40

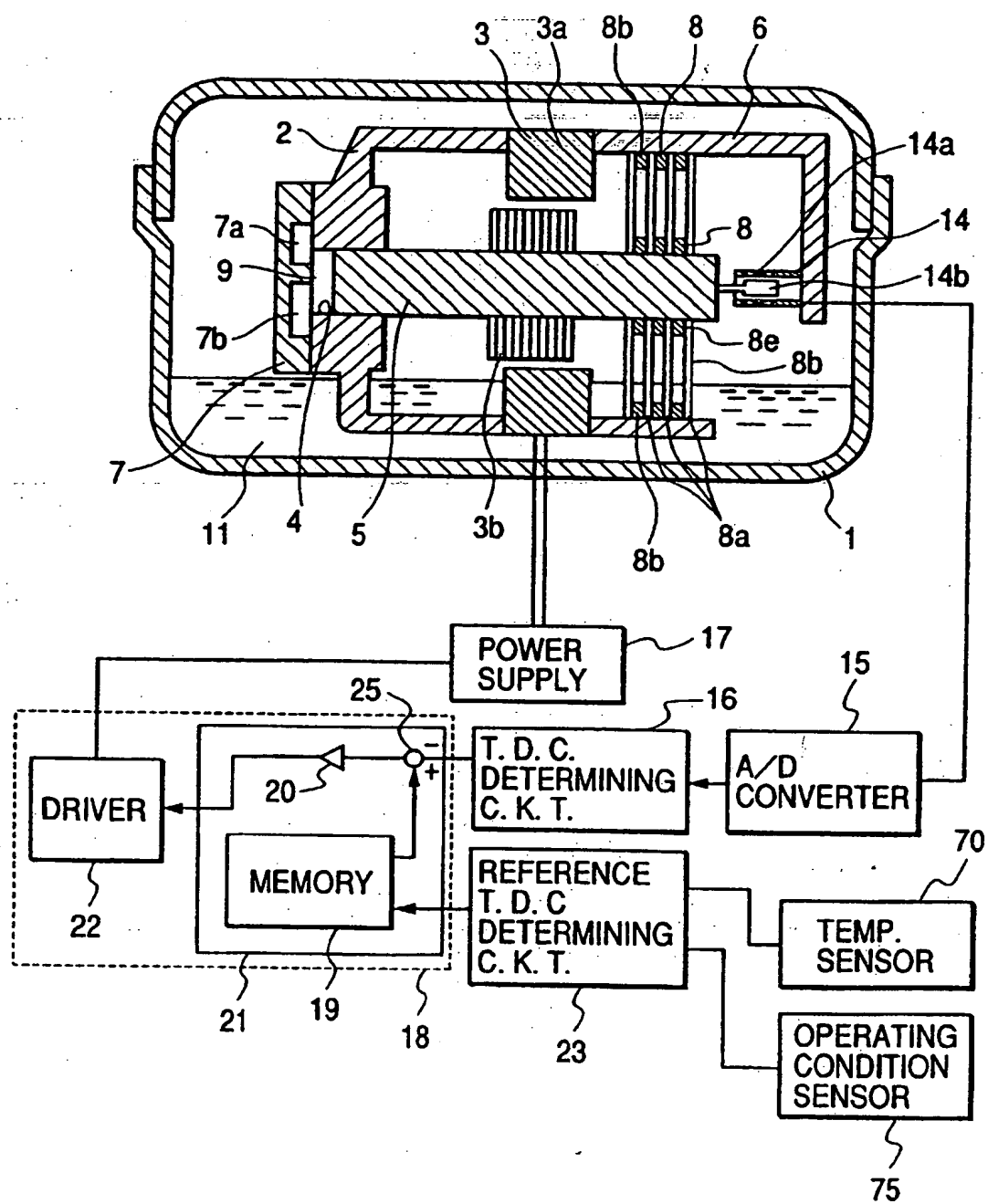
14. A linear motor according to claim 13, wherein each of the holders is made of a C-shaped member having disposed therein one of the blocks. 45

50

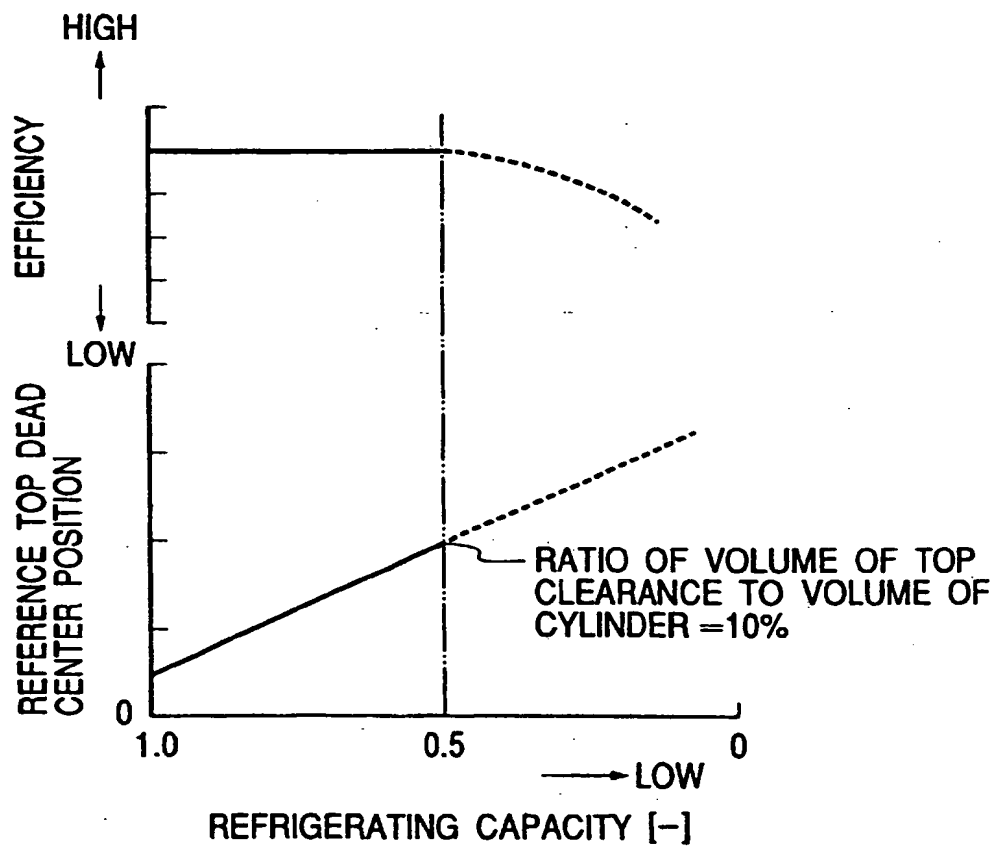
55



FIG. 1



**FIG. 2**



**FIG. 3**

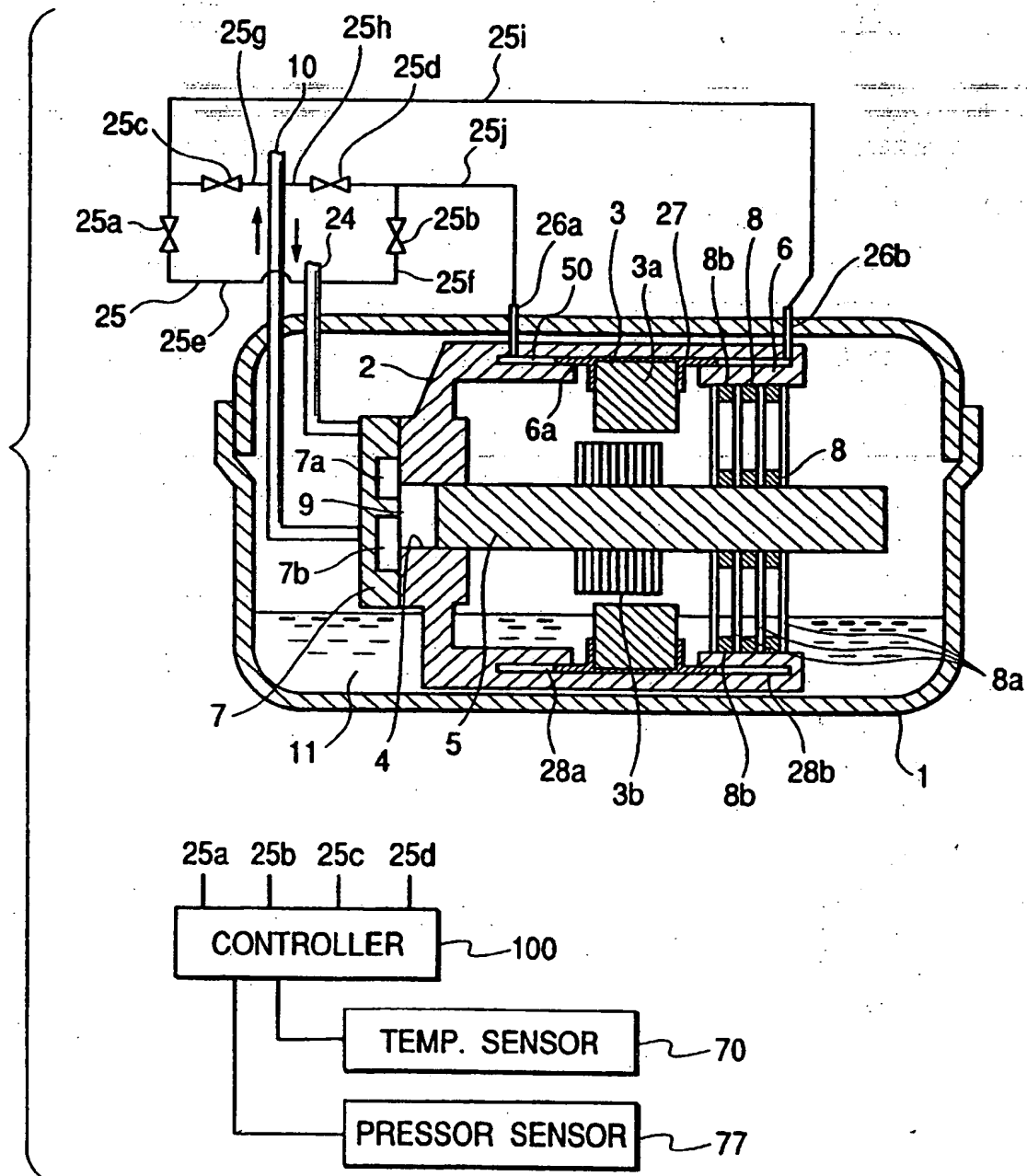


FIG. 4

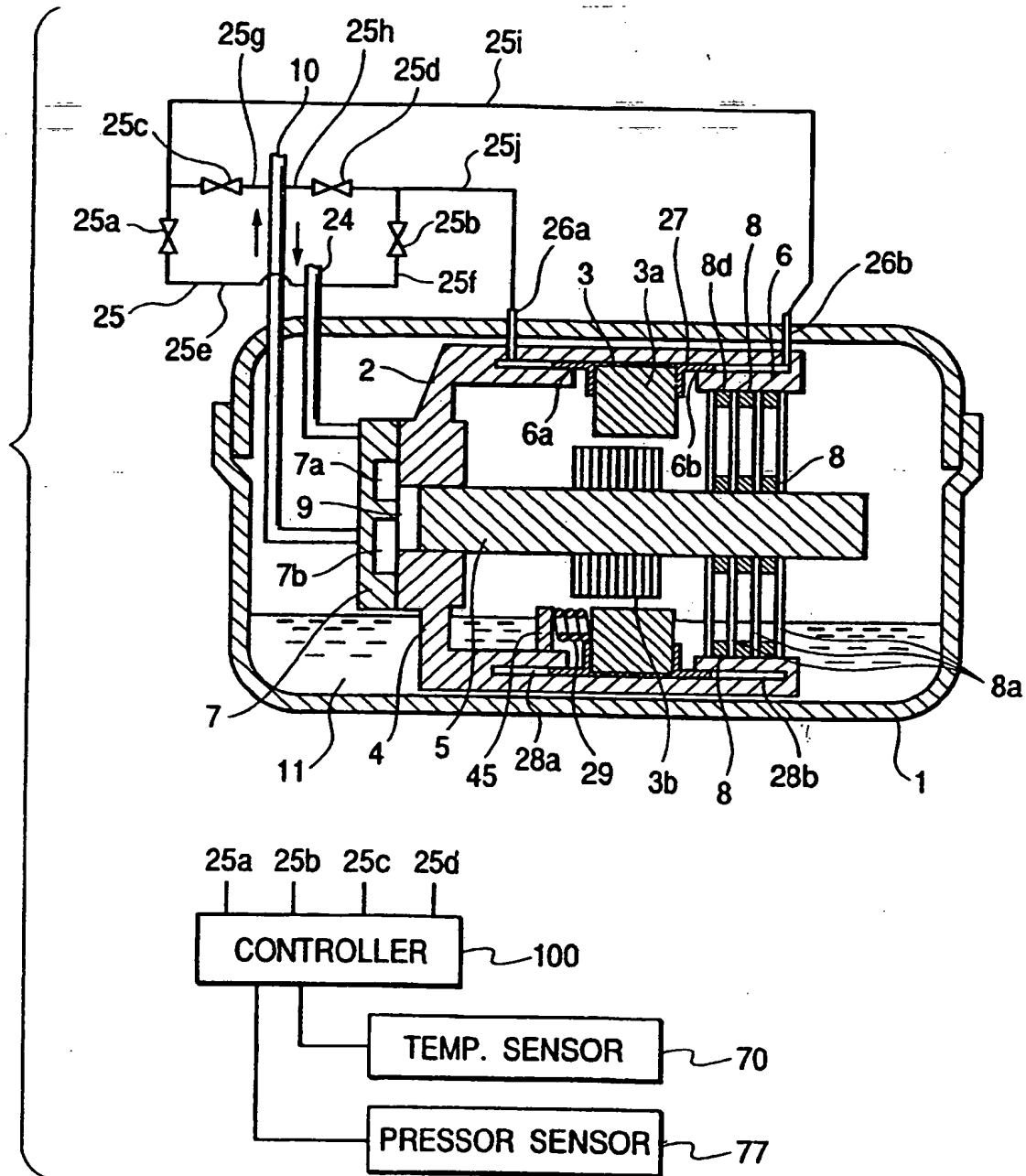


FIG. 5

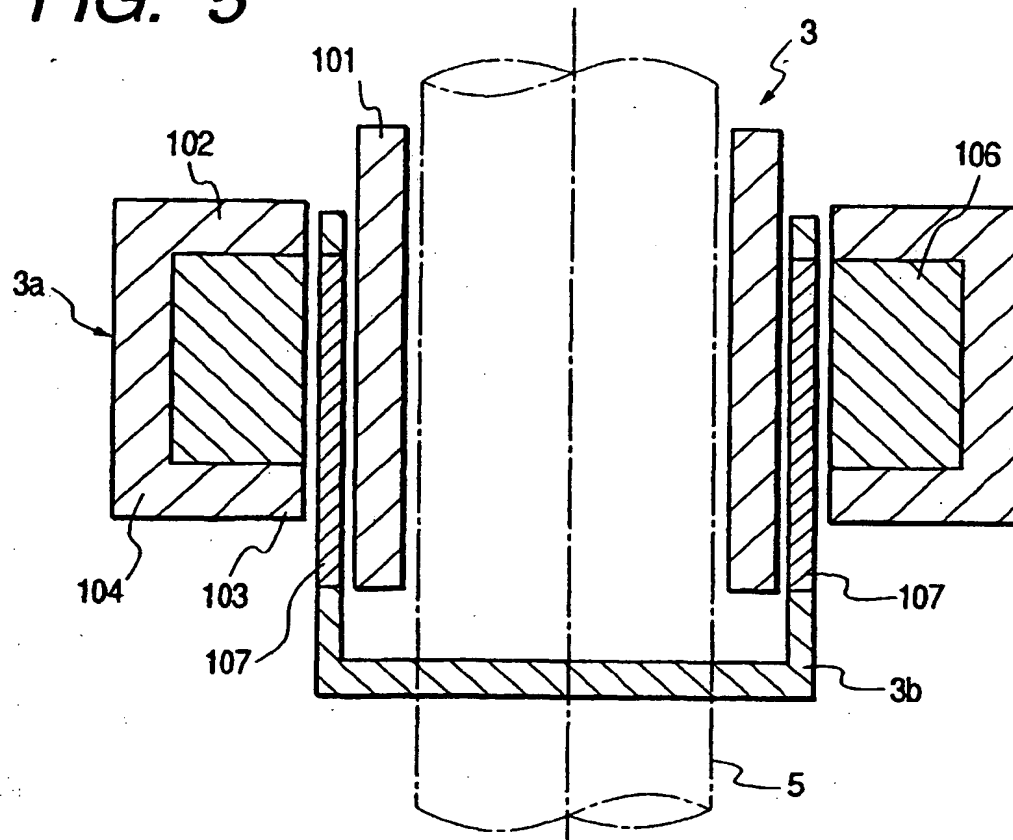


FIG. 6

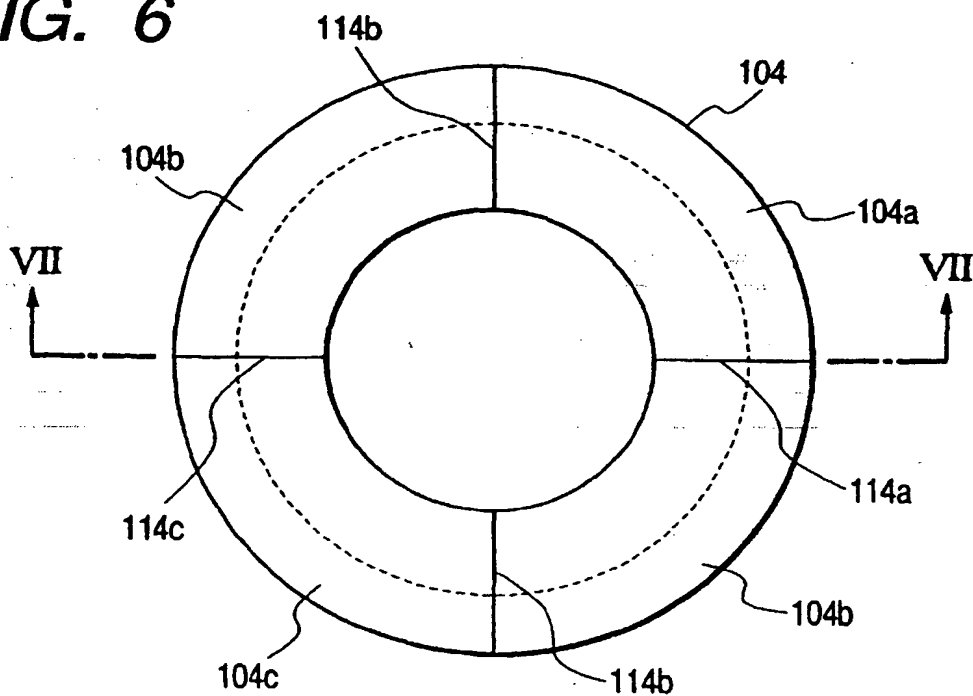


FIG. 7

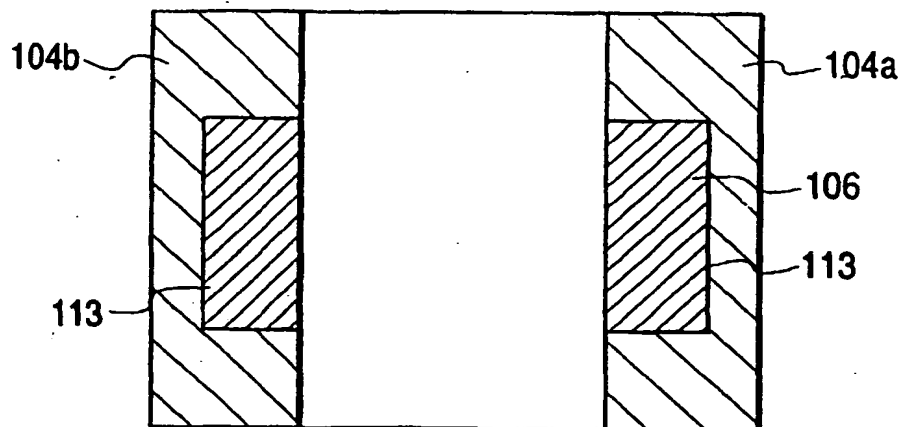


FIG. 8

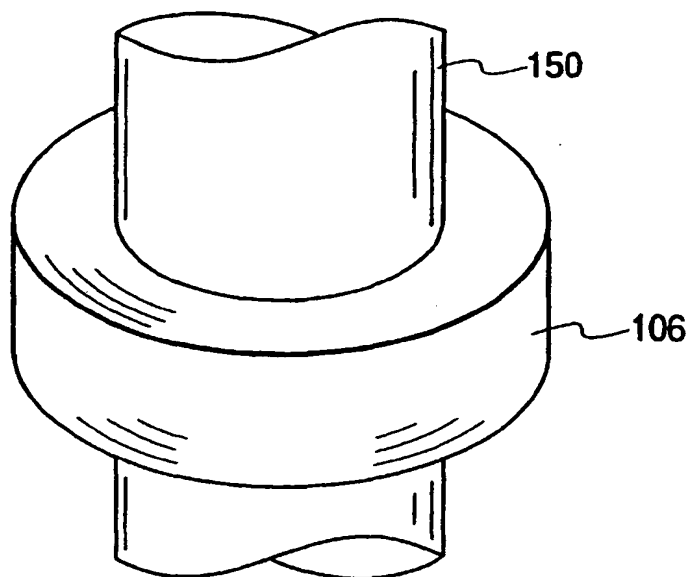


FIG. 9

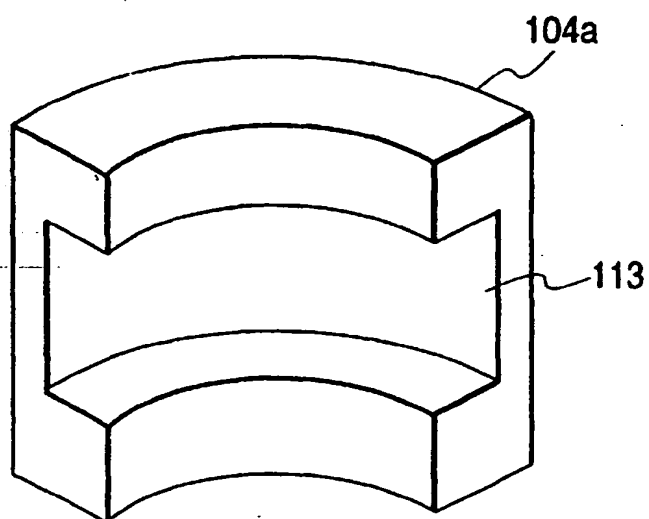


FIG. 10

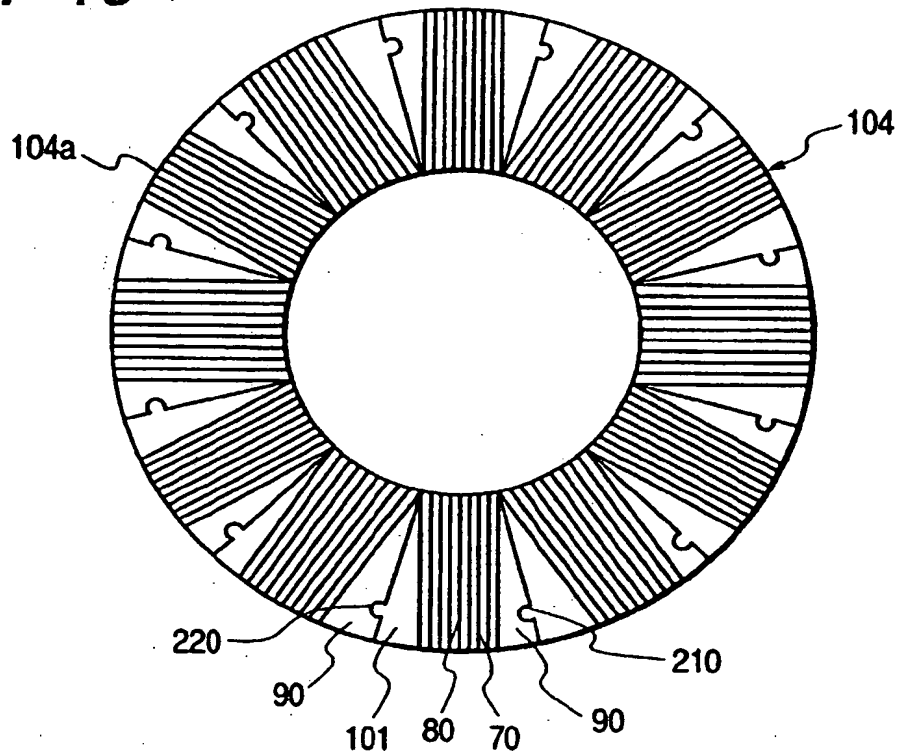


FIG. 11

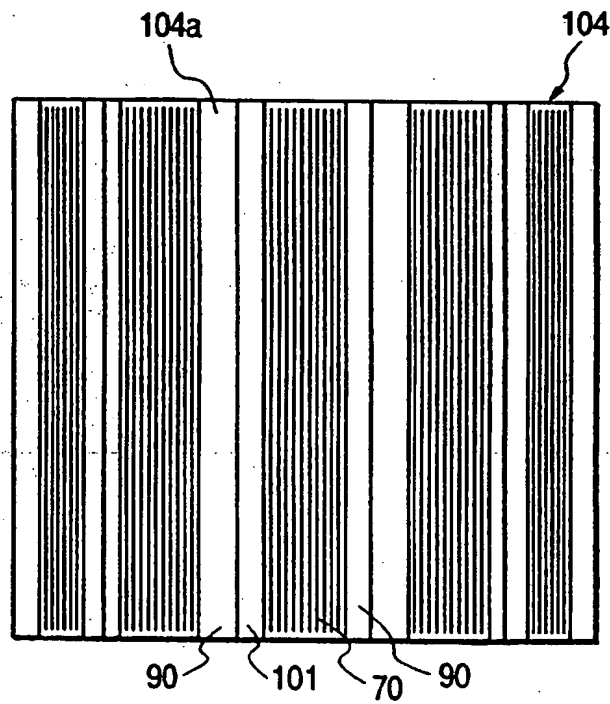


FIG. 12

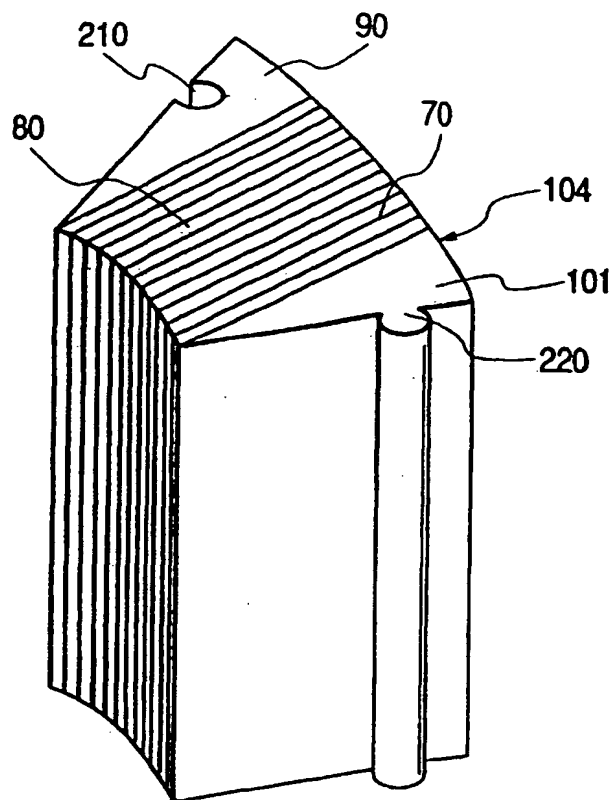
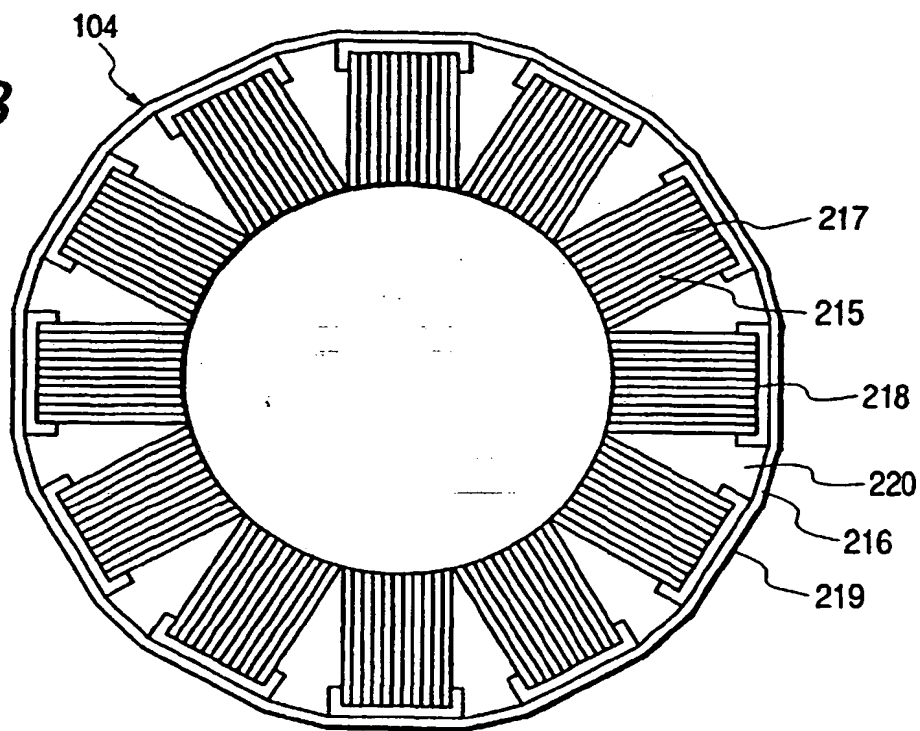
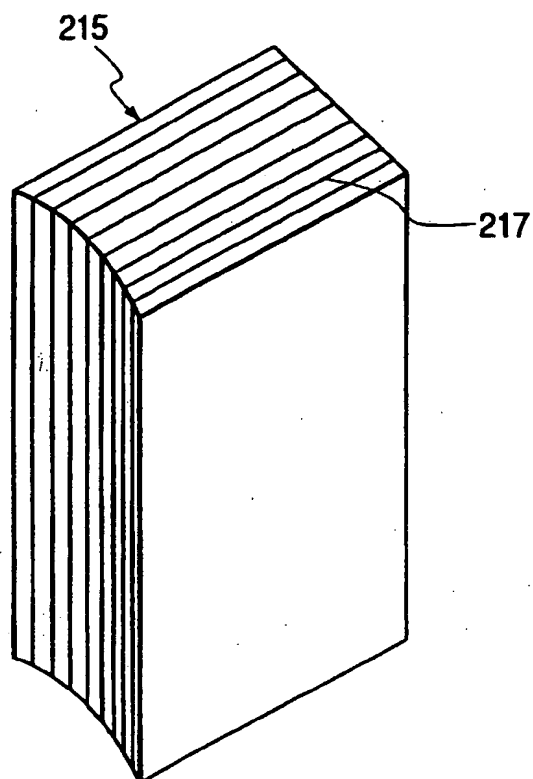


FIG. 13

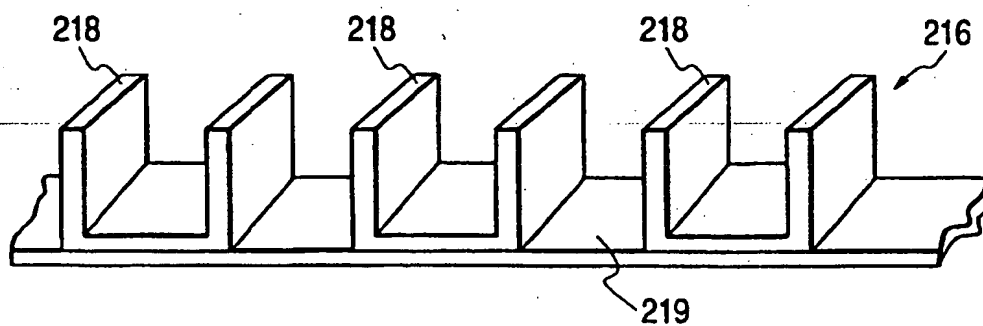




**FIG. 14**



**FIG. 15**





European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 98 30 9534

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 4 353 220 A (CURWEN PETER W ET AL) 12 October 1982 (1982-10-12) * column 2, line 61 - column 11, line 42 * ---	1-6	F04B35/04 F04B49/06 H02K33/16 H02K33/10 H02K1/12 H02K1/20
X	EP 0 774 580 A (MATSUSHITA ELECTRIC IND CO LTD ;MATSUSHITA REFRIGERATION (JP)) 21 May 1997 (1997-05-21) * column 9, line 32 - column 11, line 41 * * column 16, line 38 - column 17, line 13 * * column 18, line 44 - column 19, line 14 * * column 20, line 22 - column 21, line 12 * ---	1-3	
A	US 4 613 285 A (SATO EIJI ET AL) 23 September 1986 (1986-09-23) * column 3, line 65 - column 5, line 43 * ---	1-6	
A	US 4 864 176 A (MILLER WILLIAM H ET AL) 5 September 1989 (1989-09-05) * abstract; figure 2 * ---	7	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	US 5 081 381 A (NARASAKI TETSUJI) 14 January 1992 (1992-01-14) * column 3, line 37 - column 3, line 57 * ---	7	F04B H02K G05B
A	US 4 543 502 A (JARRET JACQUES H ET AL) 24 September 1985 (1985-09-24) * column 2, line 32 - column 2, line 47; figure 3 * ---	8-12	
A	PATENT ABSTRACTS OF JAPAN vol. 011, no. 113 (E-497), 9 April 1987 (1987-04-09) & JP 61 262063 A (HITACHI LTD), 20 November 1986 (1986-11-20) * abstract; figure 1 * ---	8-12	
		-/--	
The present search report has been drawn up for all claims			
Place of search <b>THE HAGUE</b>		Date of completion of the search <b>1 September 1999</b>	Examiner <b>Ramos, H</b>
<p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

EPO FORM 1503 03/02 (P04C01)



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 98 30 9534

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 5 415 529 A (LE BOUCHER LAURENT ET AL) 16 May 1995 (1995-05-16) * figure 1 *	8-12	
A	EP 0 833 427 A (MATSUSHITA ELECTRIC IND CO LTD) 1 April 1998 (1998-04-01) * figure 1 *	12	
A	US 5 300 845 A (FANNING ALAN W ET AL) 5 April 1994 (1994-04-05) * abstract; figure 3 *	13,14	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
The present search report has been drawn up for all claims			
Place of search <b>THE HAGUE</b>		Date of completion of the search <b>1 September 1999</b>	Examiner <b>Ramos, H</b>
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03/82 (P04C01)



European Patent  
Office

Application Number

EP 98 30 9534

### CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- ☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):
- ☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

### LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- ☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.
- ☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.
- ☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:
- ☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:



European Patent  
Office

**LACK OF UNITY OF INVENTION  
SHEET B**

Application Number  
**EP 98 30 9534**

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

**1. Claims: 1-6**

Correction of piston position for a linear compressor according to ambient temperature as parameter

**2. Claim : 7**

Fitting of a coil for the stator of an electric motor into an annular structure consisting of separate arc-shaped grooved blocks

**3. Claims: 8-14**

Insertion of laminations of lower permeability (=higher magnetic resistance) on the peripheral section of the outer yoke

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 98 30 9534

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

01-09-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4353220 A	12-10-1982	NONE	
EP 0774580 A	21-05-1997	JP 9137781 A US 5897296 A	27-05-1997 27-04-1999
US 4613285 A	23-09-1986	JP 60209676 A DE 3566017 A EP 0161429 A	22-10-1985 08-12-1988 21-11-1985
US 4864176 A	05-09-1989	AU 612891 B AU 4044489 A CA 1303108 A EP 0426751 A JP 2079756 A WO 9001824 A	18-07-1991 05-03-1990 09-06-1992 15-05-1991 20-03-1990 22-02-1990
US 5081381 A	14-01-1992	JP 2651734 B JP 3243161 A FR 2660125 A	10-09-1997 30-10-1991 27-09-1991
US 4543502 A	24-09-1985	FR 2544926 A EP 0123617 A JP 60020756 A	26-10-1984 31-10-1984 02-02-1985
JP 61262063 A	20-11-1986	NONE	
US 5415529 A	16-05-1995	FR 2698742 A CZ 9302539 A DE 69307667 D EP 0600759 A JP 6209561 A	03-06-1994 15-06-1994 06-03-1997 08-06-1994 26-07-1994
EP 0833427 A	01-04-1998	JP 10155248 A	09-06-1998
US 5300845 A	05-04-1994	CA 2119800 A DE 69407093 D EP 0626749 A JP 6311724 A US 5525852 A	06-10-1994 15-01-1998 30-11-1994 04-11-1994 11-06-1996

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82